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DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CONDITION SURVEY

Report No. 89-181-K

E.J. McColm
Engineer
Concrete Technology Section
Civil Research Department

ABSTRACT

A concrete condition survey was carried out on the Beaver Dams Pumphouse. In a portion of the north abutment walls and the deck, the concrete was found to be deteriorated. Cracking with efflorescence was noted on the surface of the piers supporting the pumphouse; however, the interior concrete from these piers was of good quality, with an average compressive strength of 50.8 MPa. Based on this survey, it is recommended that the deteriorated concrete in the abutment walls and the deck be removed and replaced. During this remedial work, it may be found that some of the surface concrete in the piers will also require removal and replacement.

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To Mr. O. Bernaus
Manager
Civil Maintenance Department
Hydraulic Generation Group

Attention: Mr. L.W. Coley/Mr. S.L. Forndron

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CONDITION SURVEY

1.0 INTRODUCTION

As requested by Mr. S.L. Forndron of the Civil Maintenance Department, a concrete condition survey of the Beaver Dams Pumphouse was conducted by the Concrete Technology Section, Civil Research Department. The survey included the drilling of concrete cores to assess the quality of the concrete and to provide specimens for laboratory testing. Visual observations were also made to determine the extent of concrete deterioration. The field work, consisting of the drilling and visual observations, was carried out from May 8 to 10, 1989.

The results of the concrete condition survey, including the laboratory testing of specimens, are summarized in this report.

2.0 CONCRETE CORING

The concrete coring was conducted with an electric drill, using a nominal 100 mm diameter diamond bit. A sketch of the structure, showing the drill locations, is shown in Figure 1. Fifteen cores were drilled as follows: six (Cores BD2 to BD4 and Cores BD12 to BD14) were drilled vertically through the deck into the pumphouse piers, seven (Cores BD5 to BD11) were drilled horizontally into the abutment walls, and two (Cores BD1 and BD15) were drilled vertically into the abutment walls. A concrete core log is given in Appendix A.

From these cores, specimens were selected for laboratory testing to determine the physical properties of the concrete. The results of the compressive strength (ASTM C 42), density, and absorption (ASTM C 642) tests are given in Table 1. The specimens used for the compressive strength and density tests were saturated in water at 23°C for 48 hours. For the absorption test, the specimens were saturated at 23°C as specified in ASTM C 642.

3.0 OBSERVATIONS AND DISCUSSIONS

The north and south abutments, on both ends of the pumphouse, consist of concrete walls enclosing gravel and rock fill (Figures 1 to 3). The concrete in the walls of the south abutment appears to be in good condition. A few vertical cracks with efflorescence are present in the exterior and interior walls. Core BD1, drilled vertically from the upstream side of the south abutment, represents good quality concrete with a compressive strength of over 40 MPa. Because of the quality of the concrete in this core and the good visual appearance of the walls, no additional coring was conducted in this abutment.

The exterior north abutment, particularly near the top of the walls, contains areas of extensive horizontal cracking with heavy efflorescence. On the downstream face of the abutment, the deterioration of the concrete has exposed reinforcing steel. Some of the interior walls are also cracked and spalled on the top surface. Concrete cores were drilled horizontally through the upstream (Cores BD5 to BD9, Figure 4) and downstream (Cores BD10 and BD11, Figure 5) exterior walls and vertically through one of the interior walls (Core BD15). These cores confirm that the concrete in some locations is extensively deteriorated. Near the top, in areas of extensive surface cracking, the concrete is completely cracked through the width of the walls. The extent of concrete deterioration varies and is represented by external cracking and efflorescence on the surface of the walls. The apparent cause of this is freeze/thaw cycling of the saturated concrete.

During the drilling of Cores BD10 and BD11 in the north abutment, a large flow of water was encountered when the downstream wall was penetrated. This indicates poor drainage of the rock fill area behind the concrete wall.

The four piers supporting the pumphouse exhibit surface cracking, with efflorescence and minor spalling (Figures 6 and 7). In a few locations, reinforcing steel is exposed. Six cores (Cores BD2 to BD4 and BD12 to BD14) were drilled vertically through the deck into the piers. Because of the presence of vertical reinforcing steel, the cores were drilled from 150 to 410 mm from the face of the piers. Access restrictions prevented the horizontal drilling of cores. The concrete obtained from the piers is of good quality, with average compressive strength, density, and absorption of 50.8 MPa, 2415 kg/m^3, and 6.3%, respectively.

Along the edges of the deck, the concrete has cracked and spalled, and in one location, on the downstream side of the pumphouse, a hole has developed (Figure 8). In most of the cores drilled through the deck (Cores BD2 to BD4 and BD12 to BD14), the concrete was recovered as rubble or found to be extensively cracked.

The condition of the concrete in the powerhouse was not included in this condition survey.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 The concrete in the south abutment appears to be in good condition, with a compressive strength over 40 MPa.

4.2 The concrete in some sections of the north abutment is extensively deteriorated. The areas of poor quality concrete are identified by horizontal cracking and efflorescence on the exterior surface of the walls. The probable cause of this deterioration, which is most severe at the top of the walls, is cycles of freezing and thawing of the saturated concrete.

4.3 In general, the concrete in the piers appears to be in good condition, with some cracking and minor spalling. From laboratory tests on specimens from the interior concrete, the compressive strength, density, and absorption were found to average 50.8 MPa, 2415 kg/m^3, and 6.3%, respectively. During rehabilitation work, it may be found that the exterior cracked concrete in the upper portion of these piers may have to be removed and replaced.

4.4 The deck is in poor condition, and the concrete is extensively deteriorated in some locations.

4.5 It is recommended that the deteriorated concrete in the north abutment and the deck be removed and replaced. During the replacement of the deck, repairs may be required to some of the piers as per Section 4.3.

4.6 The significance of the apparent poor drainage behind the walls of the north abutment should also be assessed.

Approved by:

for T.W. Klym
Manager
Civil Research Department

Prepared by:

E.J. McColm
Engineer
Concrete Technology Section

Reviewed by:

G.S. Kellay
Supervising Engineer
Concrete Technology Section

EJM:cs

TABLE 1

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
LABORATORY TEST RESULTS OF CONCRETE CORES

Core Number	Specimen Number	Length of Test Specimen* (mm)	Compressive Strength** (MPa)	Density** (kg/m^3)	Absorption 48-Hour Immersion (%)	Remarks***
BD1	1-1B	200	58.3	2435	-	Void (10 mm) in specimen.
	1-2A	180	-	2385	5.8	
	1-3A	110	-	2347	6.9	
	1-3B	200	41.9	2404	-	
BD2	2-4B	201	58.8	2448	-	
	2-4C	110	-	2454	4.8	
	2-5B	201	49.9	2454	-	
	2-6B	201	48.6	2438	-	
	2-6C	112	-	2419	5.7	
BD3	3-3A	150	-	2385	7.0	
	3-4B	157	38.7	2432	-	Compressive strength result adjusted due to specimen length as per ASTM C 42.
	3-5B	201	46.3	2428	-	
	3-6A	80	-	2430	5.9	
	3-6B	201	61.6	2427	-	

* Specimen diameter 100 mm.
** Specimens tested in a saturated state.
***Except as noted, no unusual features were observed in the test specimen.

TABLE 1 (CONT'D)

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
LABORATORY TEST RESULTS OF CONCRETE CORES

Core Number	Specimen Number	Length of Test Specimen* (mm)	Compressive Strength** (MPa)	Density** (kg/m^3)	Absorption 48-Hour Immersion (%)	Remarks***
BD4	4-1B	200	26.4	2422	-	Specimen obtained from deck concrete, crack in specimen.
	4-3A	110	-	2345	8.0	
	4-3B	200	50.5	2384	-	
	4-4A	198	45.2	2373	-	
	4-4B	140	-	2353	6.3	Large porous 60 mm aggregate particle in specimen.
BD6	6-1B	200	30.5	2389	-	Hairline crack noted near bottom of specimen.
BD7	7-1B	200	See Remarks	2395	-	Specimen broke during preparation.
BD8	8-1A	95	-	2383	6.4	
	8-1C	201	48.0	2397	-	
BD10	10-1A	130	-	2396	7.5	Cracks in specimen.
	10-1B	199	42.4	2418	-	
BD11	11-1A	130	-	2358	8.4	Cracks in specimen.
	11-1B	200	45.9	2399	-	

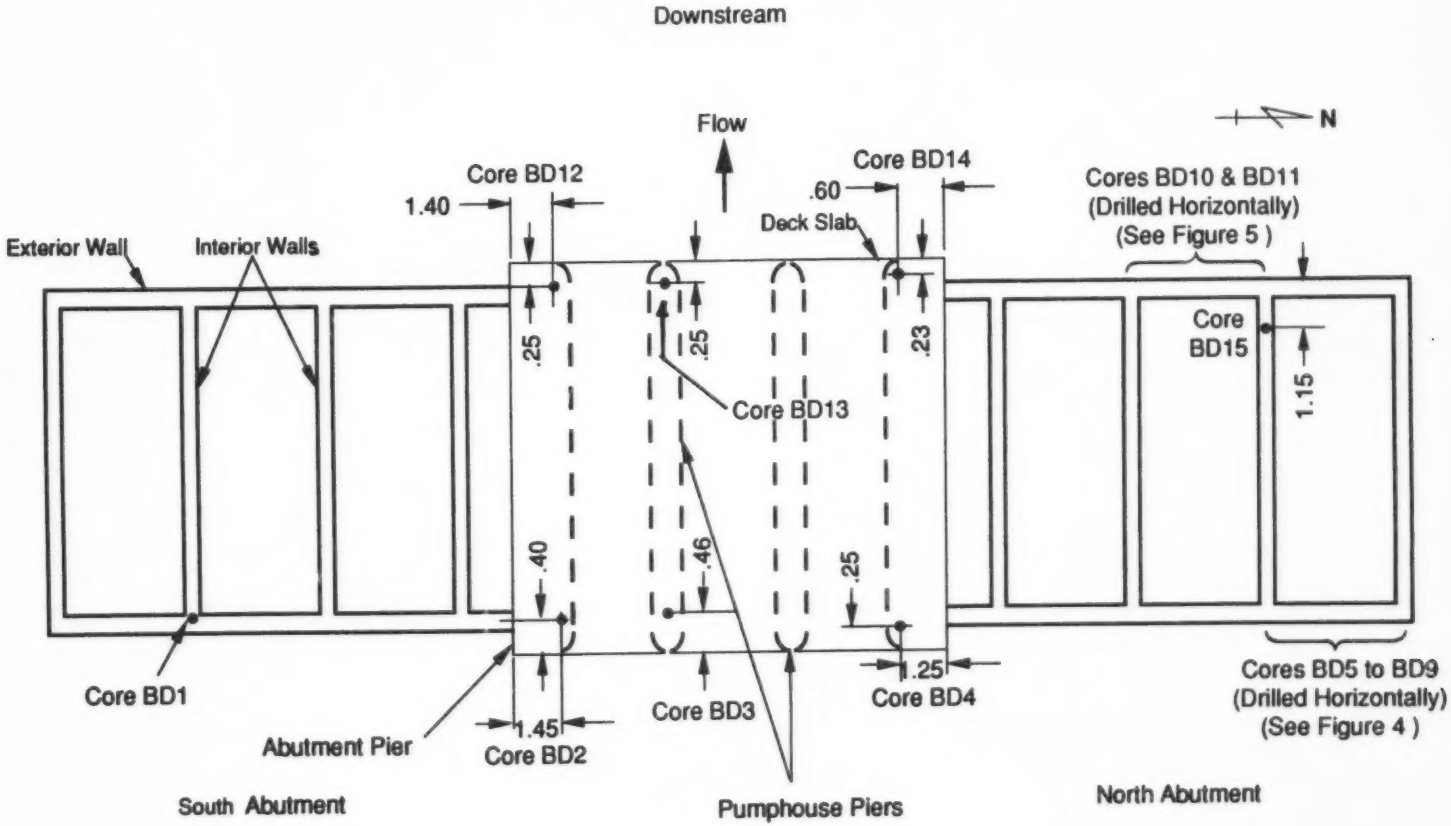
* Specimen diameter 100 mm.
** Specimens tested in a saturated state.
***Except as noted, no unusual features were observed in the test specimen.

TABLE 1 (CONT'D)

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
LABORATORY TEST RESULTS OF CONCRETE CORES

Core Number	Specimen Number	Length of Test Specimen* (mm)	Compressive Strength** (MPa)	Density** (kg/m^3)	Absorption 48-Hour Immersion (%)	Remarks***
BD12	12-3B	50	-	2417	6.8	Crack in specimen.
	12-3C	200	49.2	2417	-	
	12-4B	201	46.1	2423	-	
	12-5B	190	48.6	2395	-	
	12-5D	100	-	2400	6.3	
BD13	13-2A	85	-	2394	7.1	
	13-2B	199	43.6	2445	-	
	13-3B	201	48.2	2439	-	
	13-4B	201	53.4	2444	-	
	13-4C	40	-	2435	5.9	Specimen size non-standard (use results as a guide only).
BD14	14-3	190	-	2409	6.8	
	14-5	201	56.5	2411	-	Small piece of steel in specimen.
	14-6A	130	-	2421	5.3	
	14-6B	201	67.6	2411	-	
BD15	15-3B	201	40.1	2444	-	
	15-3C	100	-	2423	5.8	
	15-4B	201	57.2	2410	-	
	15-4C	50	-	2408	6.9	

* Specimen diameter 100 mm.
** Specimens tested in a saturated state.
***Except as noted, no unusual features were observed in the test specimen.



PLAN VIEW

Notes

1) All dimensions are approximate and are given in metres

FIGURE 1

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
LOCATION OF DRILL HOLES

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Figure 2 Upstream view of Beaver Dams Pumphouse. Note efflorescence associated with cracks in the north abutment and the top portion of the piers.

Figure 3 Downstream view of the Beaver Dams Pumphouse. Note the efflorescence associated with cracks in the north abutment and the top portion of the piers.

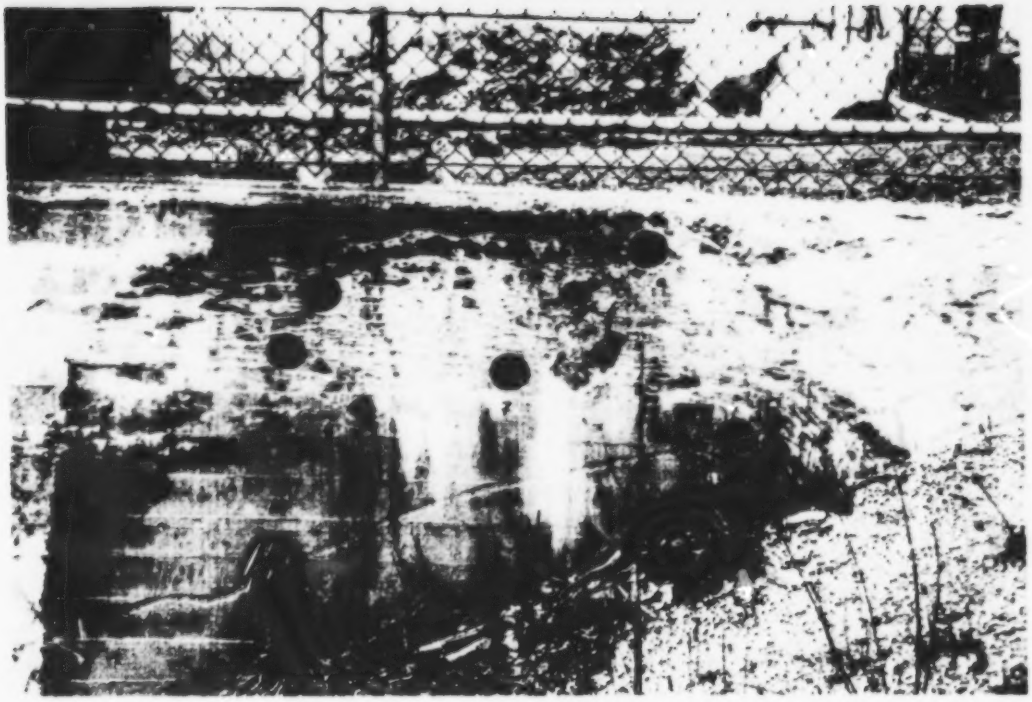

Figure 4 Location of Cores BD5 to BD9 drilled in the upstream face of the north abutment. Note the cracking and spalling of the concrete near the top of the wall.

Figure 5 Location of Cores BD10 and BD11 drilled in the downstream face of the north abutment. Note the exposed reinforcing steel near the top of the wall.

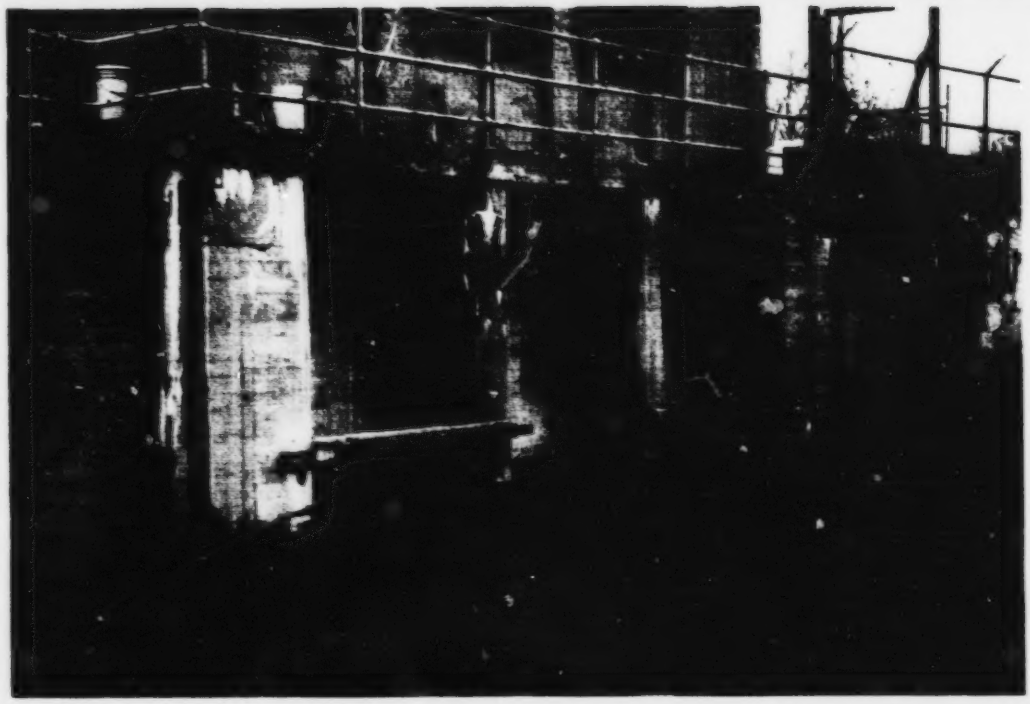

Figure 6 Upstream end of the piers supporting the pumphouse. Note the efflorescence associated with cracks in the upper portion of the piers. Exposed reinforcing can be seen in one pier.

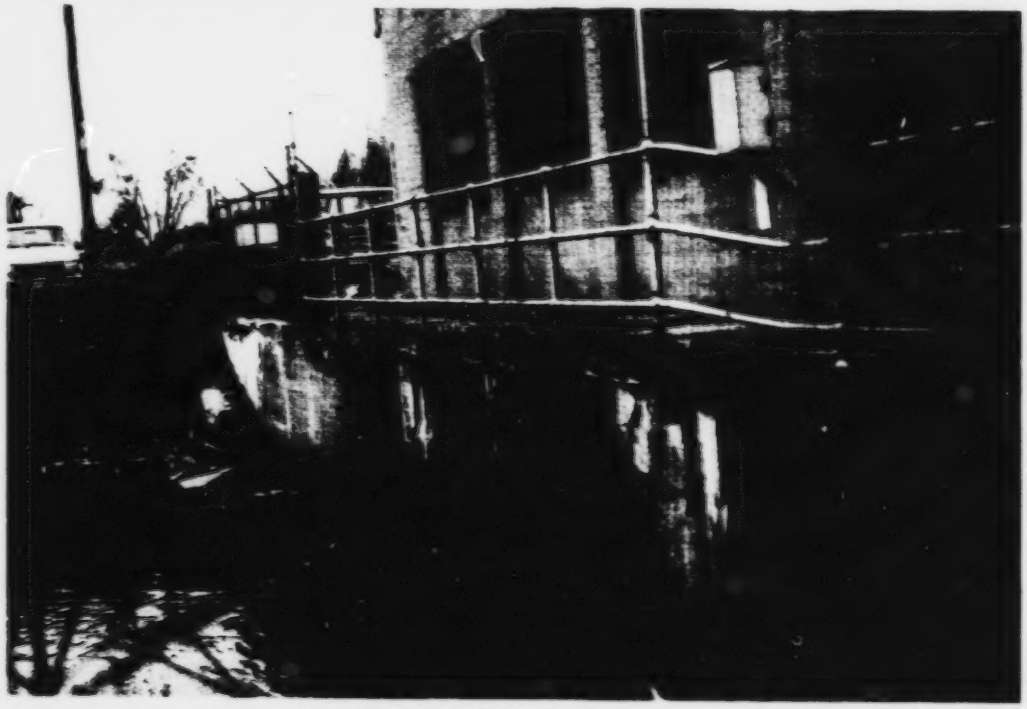

Figure 7 Downstream end of the piers supporting the pumphouse. Note the efflorescence associated with cracks in the upper portion of the piers and the north abutment wall. Reinforcing steel is exposed near the waterline in one of the piers.

Figure 8 Deterioration of the deck on the downstream side of the pumphouse. At one location, a hole has developed.

APPENDIX A

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CORE LOG

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CORE LOG

Core Number and Location (See Figure 1)	Section ID	Depth In Core Hole (mm)	Remarks
Core BD1	BD1-1	0-360	Reinforcing steel (25 mm diameter)
-Upstream side of	BD1-2	360-580	at 105 and 550 mm.
south abutment	BD1-3	580-920	Core drilled until contact with steel.
(see Figure A1)	-	920-1020	Core section not recovered.

General

- Core drilled vertically from area of good quality concrete (ie, no cracking or spalling observed).
- Maximum aggregate size 30 mm.
- Good aggregate grading and distribution.
- Localized voids to maximum size 10 mm.
- Reinforcement in good condition.
- Core breaks occur through aggregates.
- Porous aggregates noted.

Core BD2	-	0-10	Spalled concrete from the surface of the deck.
-Upstream end of	BD2-1	10-60	Reinforcing steel (20 mm diameter) at 60 mm.
south abutment pier	BD2-2	60-220	Electrical conduit (40 mm diameter) at 190 mm.
(see Figure A1)	BD2-3	220-320	Apparent contact between deck and pier at 320 mm.
	BD2-4	320-670	
	BD2-5	670-1020	
	BD2-6	1020-1370	

General

- Core drilled vertically from area of fair quality concrete (ie, some minor cracking and spalling at edge of deck).
- Maximum aggregate size 40 mm.
- Good aggregate grading and distribution.
- Extensive horizontal cracking of core to 320 mm.
- Localized voids to maximum size 15 mm.
- Minor surface corrosion of reinforcing steel.
- Core breaks occur through aggregates (except in top 320 mm).
- Porous aggregate noted.

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CORE LOG

Core Number and Location (See Figure 1)	Section ID	Depth In Core Hole (mm)	Remarks
Core BD3	-	0-15	Spalled concrete from surface of deck.
- Upstream end of	BD3-1	15-110	Core recovered as rubble.
south pumphouse pier	BD3-2	110-300	
(see Figure A1)	-	300-340	Core recovered as rubble.
	BD3-3	340-550	Diagonal crack between Sections BD3-3
	BD3-4	550-760	and BD3-4.
	BD3-5	760-1000	
	BD3-6	1000-1315	

General

- Core drilled vertically from area of poor quality concrete (ie, spalling observed on surface of deck and cracking with efflorescence observed on pier).
- Maximum aggregate size 30 mm.
- Good grading of aggregate.
- Fair distribution of aggregate (ie, some sections contain primarily small size aggregates).
- Horizontal cracks in core to 340 mm.
- Localized voids to maximum size 7 mm.
- Core breaks occur through aggregates (except in top 340 mm).
- Porous aggregates noted.
- Small pieces of wood present.

Core BD4			
- Upstream end of	BD4-1	0-250	Top surface of deck slightly scaled.
north abutment pier	BD4-2	250-540	Reinforcing steel (25 mm diameter) at
(see Figure A1)			490 and 530 mm.
	BD4-3	540-880	Vertical construction joint intersected from 320 to 630 mm (open along portion of Section BD4-2).
	BD4-4	880-1230	Large brick-like aggregate (60 x 100 mm) at 1070 mm.

General

- Core drilled vertically from area of fair quality concrete (ie, spalling observed on surface of deck and cracking with efflorescence observed on pier).
- Maximum aggregate size 30 mm.
- Good grading of aggregate.
- Fair distribution of aggregate (ie, some sections contain primarily small size aggregates).
- Localized voids to maximum size 10 mm.
- Core breaks occur through aggregates.

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CORE LOG

Core Number and Location (See Figure 1)	Section ID	Depth In Core Hole (mm)	Remarks
Core BD5 to BD9 - Upstream exterior wall of north abutment (see Figure A2)	BD5-1	0-90	Extensive cracking of core. Reinforcing steel (20 mm diameter) at 90 mm.
	-	90-190	Electrical conduit at 190 mm -drilling terminated. Core recovered as rubble.
	BD6-1	0-350	Core drilled through wall. Horizontal cracking in core to 100 mm.
	BD7-1	0-350	Core drilled through wall. Horizontal cracking in core to 110 mm.
	BD8-1	0-350	Core drilled through wall. No cracking noted.
	BD9-1	0-350	Core drilled through wall. Entire core recovered as rubble.

General

- Cores drilled horizontally through various qualities of concrete;
  - Core BD8 good quality (ie, no cracking);
  - Cores BD6 and BD7 fair quality (ie, some cracking and efflorescence);
  - Cores BD5 and BD9 poor quality (ie, extensive cracking and efflorescence).
- Maximum aggregate size 25 mm.
- Good aggregate grading and distribution.
- Degree of cracking and deterioration of concrete varies with location on the wall.
- Porous aggregate present.

Core BD10 and BD11 - Downstream exterior wall of north abutment (see Figure A3)	BD10-1	0-350	Core drilled through wall. Horizontal cracking in core to 80 mm.
	BD11-1	0-350	Core drilled through wall. Horizontal cracking in core to 100 mm.

General

- Cores drilled horizontally from area of fair quality concrete (ie, some cracking and efflorescence).
- Maximum aggregate size 25 mm.
- Good aggregate grading and distribution.
- Porous aggregates present.

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CORE LOG

Core Number and Location (See Figure 1)	Section ID	Depth In Core Hole (mm)	Remarks
Core BD12			
- Downstream end of	-	0-5	Concrete scaled from surface of deck.
south abutment pier	BD12-1	5-260	Reinforcing steel (15 mm diameter)
(see Figure A4)	BD12-2	260-290	at 290, 590 and 910 mm.
	BD12-3	290-620	
	BD12-4	620-930	
	BD12-5	930-1255	

General

- Core drilled vertically from area of fair quality concrete (ie, spalling observed on surface of deck and cracking with efflorescence observed on pier).
- Initial attempt at drilling Core BD12 was abandoned because vertical reinforcing steel was encountered; deck concrete in this core was badly cracked over its entire length.
- Maximum aggregate size 30 mm.
- Good aggregate grading.
- Fair aggregate distribution (ie, some sections of core contain primarily small coarse aggregate particles).
- Cracking in core to 50 mm.
- Localized voids to maximum size 10 mm.
- Minor surface corrosion of reinforcing steel at 290 mm.
- Core breaks occur through mortar and aggregates.
- Porous aggregates noted.

Core BD13			
- Downstream end of	-	0-5	Concrete spalled from surface of deck.
south pumphouse pier	BD13-1	5-280	Reinforcing steel (15 mm diameter) at
(see Figure A4)	BD13-2	280-610	50 and 260 mm.
	BD13-3	610-930	
	BD13-4	930-1200	

General

- Core drilled vertically from area of poor quality concrete (ie, spalling observed on surface of deck and cracking with efflorescence observed on pier).
- Maximum aggregate size 40 mm.
- Good aggregate grading and distribution.
- Cracking in core to 280 mm.
- Core breaks occur through aggregates.

DECEW FALLS GS
BEAVER DAMS PUMPHOUSE
CONCRETE CORE LOG

Core Number and Location (See Figure 1)	Section ID	Depth In Core Hole (mm)	Remarks
Core BD14			
- Downstream end of	BD14-1	0-150	
north abutment pier	BD14-2	150-310	
(see Figure A4)	BD14-3	310-550	Reinforcing steel (25 mm diameter) at 510 mm.
	BD14-4	550-630	Possible construction joint at 630 mm.
	BD14-5	630-980	Large aggregate particle (50 mm) at 800 mm.
	BD14-6	980-1340	

General

- Core drilled vertical from area of fair quality concrete (ie, cracking and efflorescence noted on pier).
- Maximum aggregate size 30 mm.
- Good aggregate grading and distribution.
- Cracking in core to 310 mm.
- Core breaks occur through aggregates.

Core BD15			
- Downstream end	BD15-1	0-60	
of interior wall	BD15-2	60-220	Reinforcing steel (15 mm diameter)
in north abutment	BD15-3	220-580	at 200 and 850 mm.
(see Figure A4)	BD15-4	580-850	

General

- Core drilled vertically from area of poor quality concrete (ie, extensive cracking and spalling of surface concrete).
- Maximum aggregate size 30 mm.
- Good aggregate grading and distribution.
- Extensive cracking in core to 100 mm, minor cracking to 220 mm.
- Core breaks occur through aggregates.

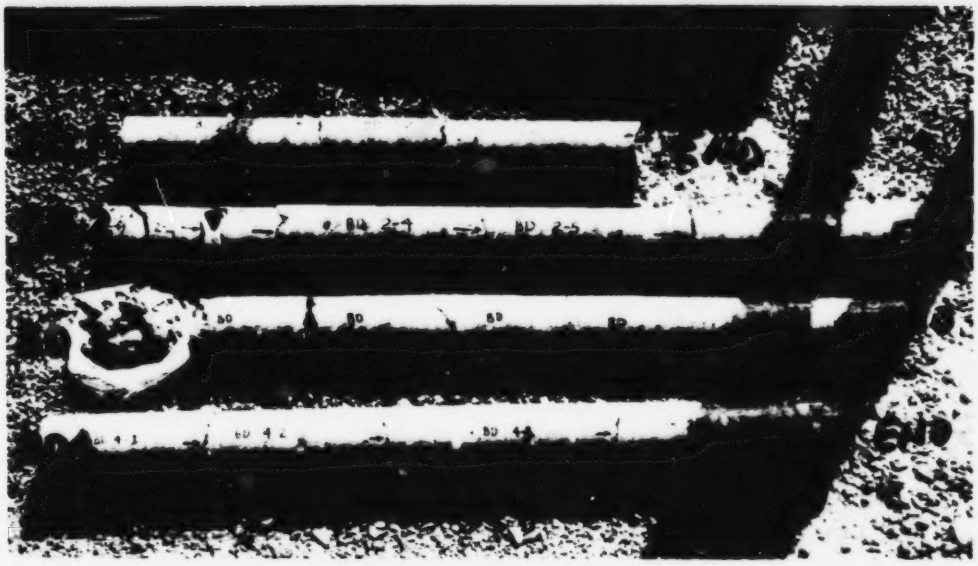

Figure A1 Cores BD1 to BD4 (nominal 100 mm diameter) drilled vertically from the upstream side of the south abutment and the pumphouse (see Figure 1 for the core locations).

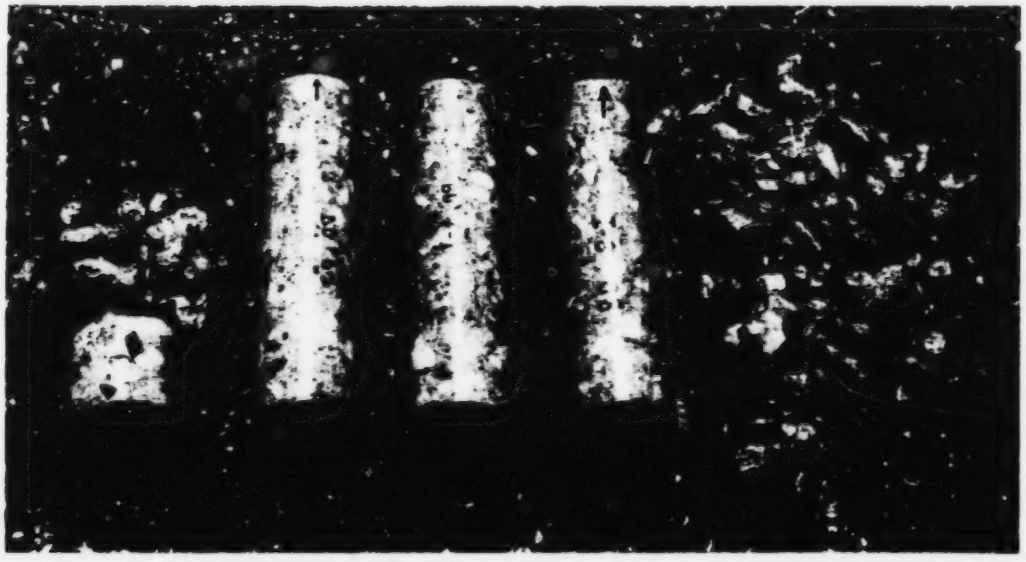

Figure A2 Cores BD5 to BD9 (nominal 100 mm diameter) drilled horizontally from the upstream side of the north abutment (see Figure 4 for the core locations).

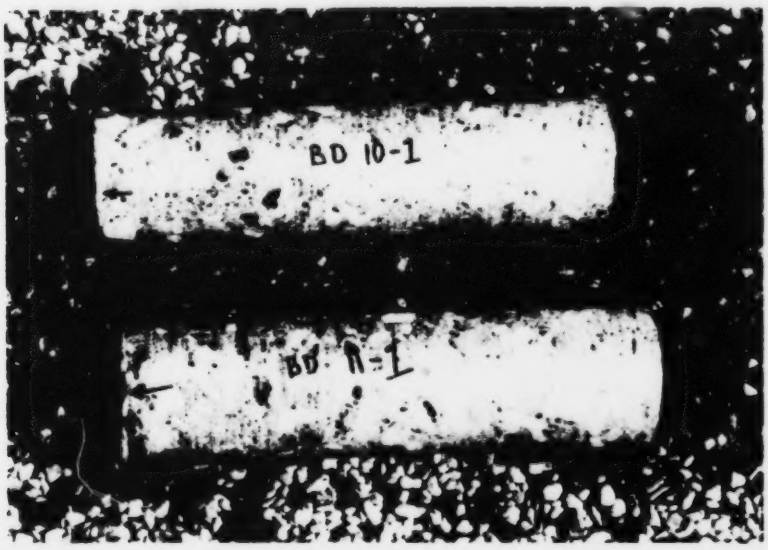

Figure A3 Cores BD10 and BD11 (nominal 100 mm diameter) drilled horizontally from the downstream side of the north abutment (see Figure 5 for the core locations).

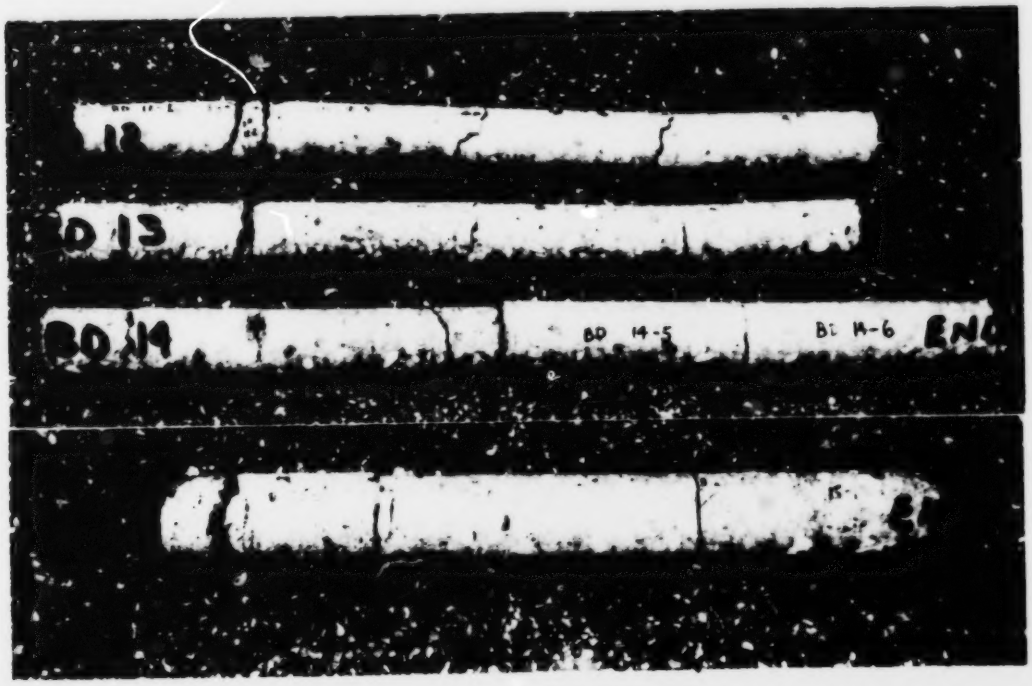

Figure A4 Cores BD12 to BD15 (nominal 100 mm diameter) drilled vertically from the downstream side of the pumphouse and north abutment (see Figure 1 for the core locations).